

Material Transfer System in Support of the Plutonium Immobilization Program

D. Pak. R. D. Merrill

This article was submitted to The American Nuclear Society Ninth International Topical Meeting on Robotics and Remote Systems, Seattle, Washington, March 4 – 8, 2001

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

December 20, 2000

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

This report has been reproduced directly from the best available copy.

Available electronically at <http://www.doc.gov/bridge>

Available for a processing fee to U.S. Department of Energy
And its contractors in paper from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-mail: reports@adonis.osti.gov

Available for the sale to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-mail: orders@ntis.fedworld.gov
Online ordering: <http://www.ntis.gov/ordering.htm>

OR

Lawrence Livermore National Laboratory
Technical Information Department's Digital Library
<http://www.llnl.gov/tid/Library.html>

MATERIAL TRANSFER SYSTEM IN SUPPORT OF THE PLUTONIUM IMMOBILIZATION PROGRAM

Donald Pak, Westinghouse Savannah River Company
c/o Lawrence Livermore National Laboratory
7000 East Avenue, Mail Stop L-394
Livermore, CA 94550
Email: pak4@llnl.gov
Telephone: (925) 422-5219

Roy D. Merrill
Lawrence Livermore National Laboratory
7000 East Avenue, Mail Stop L-394
Livermore, CA 94550
Email: merrill2@llnl.gov
Telephone: (925) 422-6448

ABSTRACT

The Plutonium Immobilization Program requires development of the process and plant prototypic equipment to immobilize surplus plutonium in ceramic for long-term storage. Because of the hazardous nature of plutonium, it was necessary to develop a remotely operable materials transfer system which can function within the confines of a glovebox. In support of this work at LLNL, such a material transfer system (MTS) was developed. This paper presents both the mechanical and controls parts making up this system, and includes photographs of the key components and diagrams of their assemblies, as well as a description of the control sequence used to validate the MTS capabilities.

1. INTRODUCTION

The Plutonium Immobilization Program requires formulation and process development to immobilize surplus plutonium in a titanate-based ceramic for long-term safe storage. Process development work has been conducted on small-scale process prototypic equipment at Lawrence Livermore National Laboratory (LLNL) in California. Final validation of the process is required to be done using plutonium material in a glovebox environment. This validation work will be conducted at the Plutonium Ceramification Test Facility (PuCTF) in LLNL. Due to the radioactive nature of the process material, remote material handling is required to protect operating personnel and environment from radiation hazards through out the process. Therefore, a remotely operable Material Transfer System (MTS) has been developed. The MTS is designed to be compatible with the process equipment in a glovebox environment. A summary of the system description and designs are provided in this paper; Section 2 describes the glovebox which contains the MTS, Section 3 presents the MTS mechanical components, and Section 4 describes the MTS controls. The focus on the mechanical design has been on the powder handling part of the process, up to the pressing operation. The rest of the mechanical system including the Material Charging Station, Press, Puck Transport, Dust Control System, Puck Measuring Station, and Furnace will not be addressed in this paper.¹ However, the overall PuCTF MTS control system covering all of the MTS mechanical systems will be presented in the System Control Section.

2. PUCTF DESCRIPTION AND EQUIPMENT LAYOUT

The immobilization process steps consist of milling the actinide oxides, blending milled actinide oxides with ceramic precursors, granulating blended powders, pressing granulated powders, and sintering pressed pucks. The final product of the ceramification process is the sintered puck, which weighs around 500g, and is 6.7 cm in diameter and 2.5 cm in thickness. The equipment being used for development testing is functionally prototypic of the proposed plant equipment. The main section of the PuCTF glovebox line is 9.2 meters long and 0.9 meter wide. The highest point of the glovebox is 2.8 meters. See Figures 1 and 2 for an isometric and actual view of the glovebox line. The main process equipment of the PuCTF glovebox line includes two attritor mills, a granulator, a press, and a furnace.

The immobilization process deals with fine powder until the powder is pressed into a puck shape. Therefore, the MTS is equipped with various features to help the powder flow freely with minimum hold-up and to minimize dust generation.

¹ Another ANS conference paper by Kurt Peterson, Westinghouse Savannah River Company, will describe the mechanical design of the puck transport and puck measuring station part of MTS.

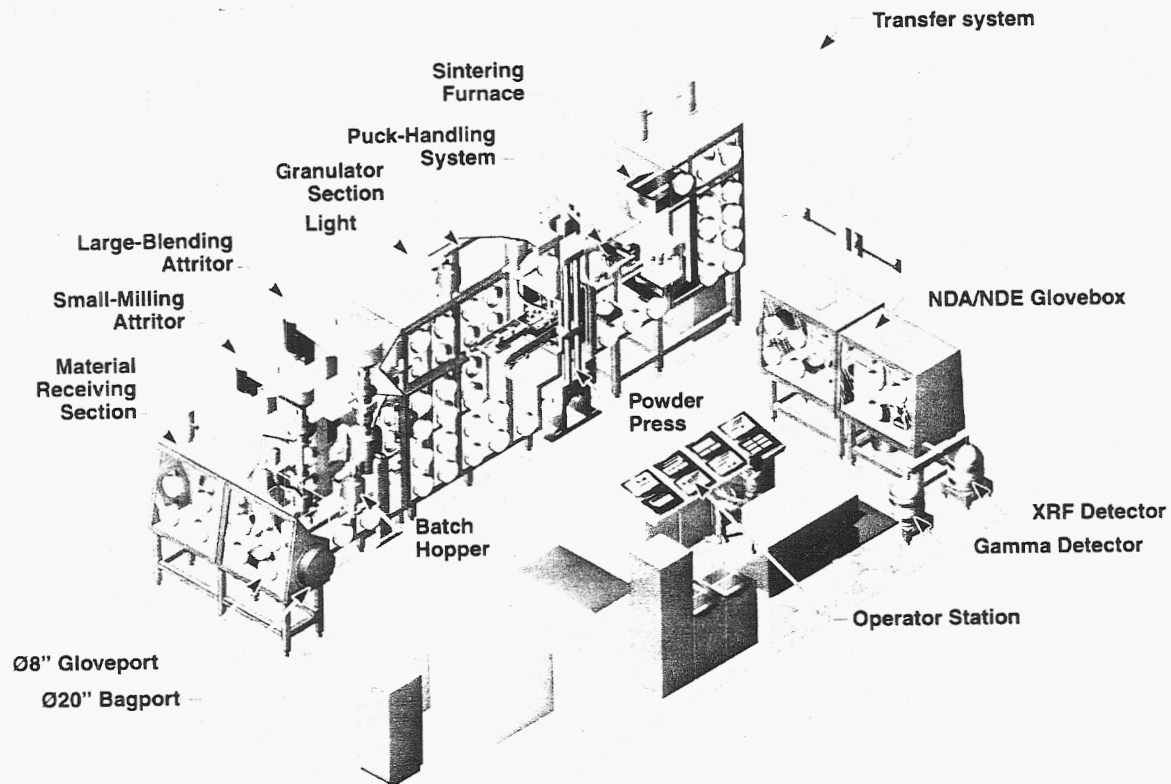


Figure 1: Conceptual layout sketch of the PuCTF.

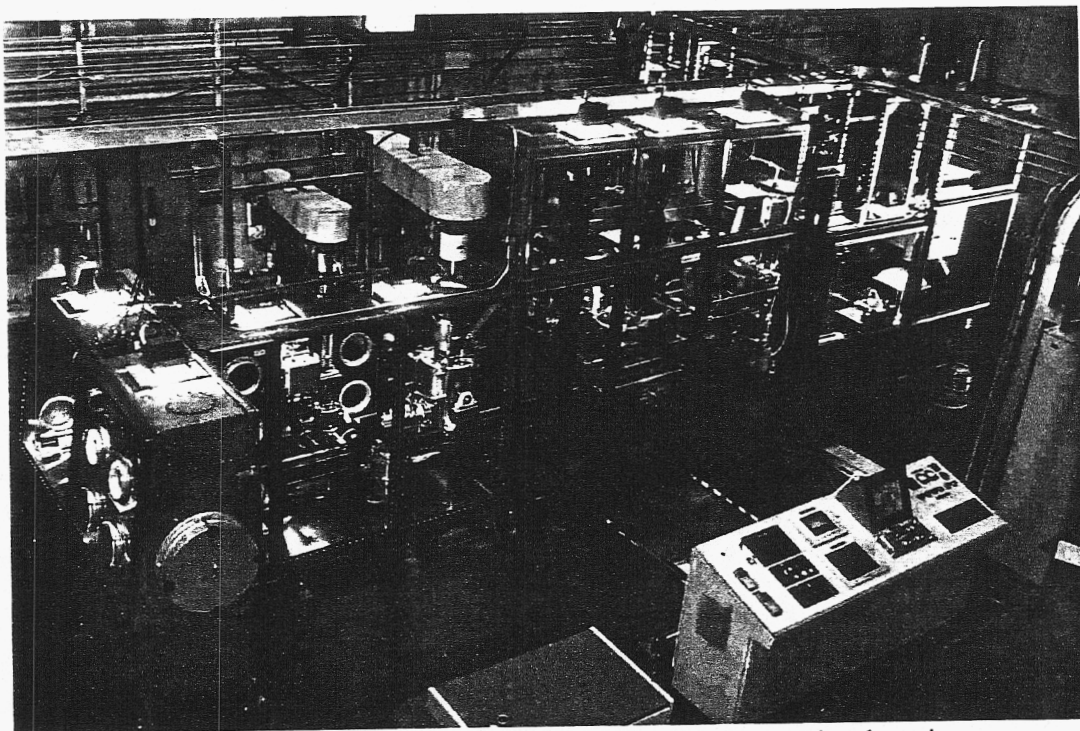


Figure 2: PuCTF assembly overview photo at the testing location.

3. MATERIAL TRANSFER SYSTEM COMPONENTS

The MTS design constraints were determined by the glovebox envelope and the process equipment configuration. It requires being simple and modular for good maintainability in a glovebox environment. The PuCTF will operate as a batch process. A single batch of material, 10 Kg total, will be processed in PuCTF at one time. The following critical mechanical components of the MTS will be discussed here.

3.1 Hoppers

3.2 Hopper Transport

3.3 Docking Stations

Process material transfer in the PuCTF is done using hoppers. Two different size hoppers are used for the process flexibility. See Figure 3 and 4. The small hopper and the large hopper have one-liter and 12 liter volume capacities, respectively.

The small hopper is equipped with a slide gate valve. The main body of the hopper is a commercially available SST (stainless steel) sanitary bottle and the gate valve is custom designed to keep it slim, lightweight, and dust tight. The small hopper assembly is 23 cm tall and 10 cm in diameter and it weighs 2.3 kg. The body and the valve assembly are connected with a single swing clamp. Therefore, it can be quickly assembled or disassembled. It has a 7.62 cm diameter opening through the valve for material charging and discharging. The interior of the hopper has an #8 finish to minimize powder sticking. The small hopper has one handle, which is mounted on the valve housing, for the hopper transport to grip during movement. The valve is designed so that it can be operated remotely. When the small hopper mates with the docking station, the pneumatic valve actuator on the docking station engages with the valve gate plate for valve operation. High-density wool felt is used as the valve gasket material to make it a dust tight operation.

The large hopper is custom designed to meet PuCTF requirements. The hopper body is made of 20 gage SST sheet metal to keep the weight down. It has a conical shape with a 30 cm maximum diameter and 60 degree angle sides. It weighs about 11 kg. The interior surface of the hopper is highly polished to give a #8 or better finish. A pneumatic vibrator is attached on the hopper body to assist with powder discharging out of the hopper. The vibrator inlet has a custom designed air fitting for remote air connection. Air source to the vibrator is provided when the hopper mates with the docking station. The hopper cover has a silicon cap with a small opening. This cap works as a sphincter seal around the equipment discharge spigot during the hopper charging operation. The silicon cap opening is covered with a spring loaded seal plate to keep it dust tight. The cover seal plate opens and closes automatically by cam action when the hopper mates with the discharge spigots of the attritor mills and the granulator. See Figure 5. The hopper is equipped with a 10 cm slide gate valve to discharge material out of the hopper. This custom designed valve has a low profile and is light weight to complement glovebox environment. High-density wool felt is used as valve seals for smooth operation and dust tightness. Two hopper handles are mounted on opposite sides of the valve housing. The hopper transporter grabs the hopper by one of these handles during any hopper movement.

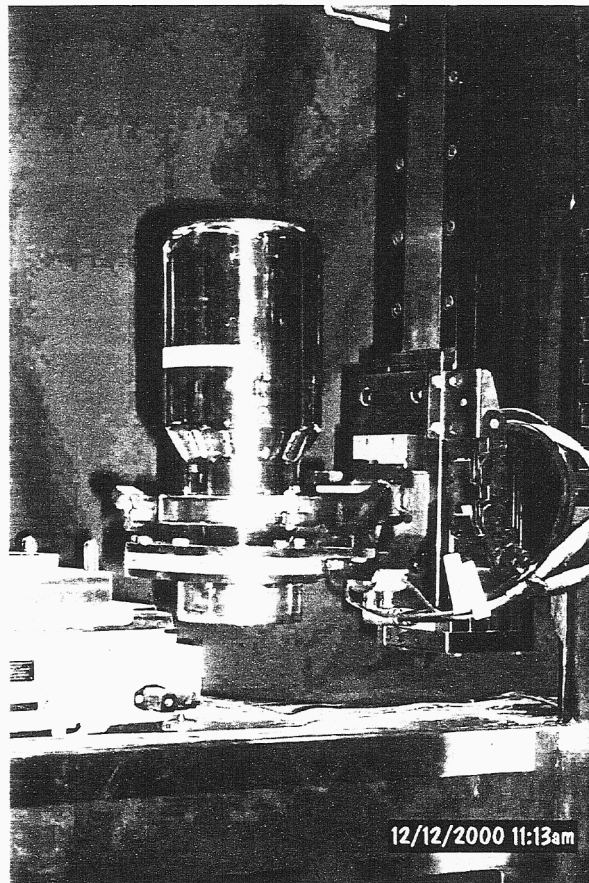


Figure 3: Photo of the Small Hopper on X1-Z1 Hopper Transporter.

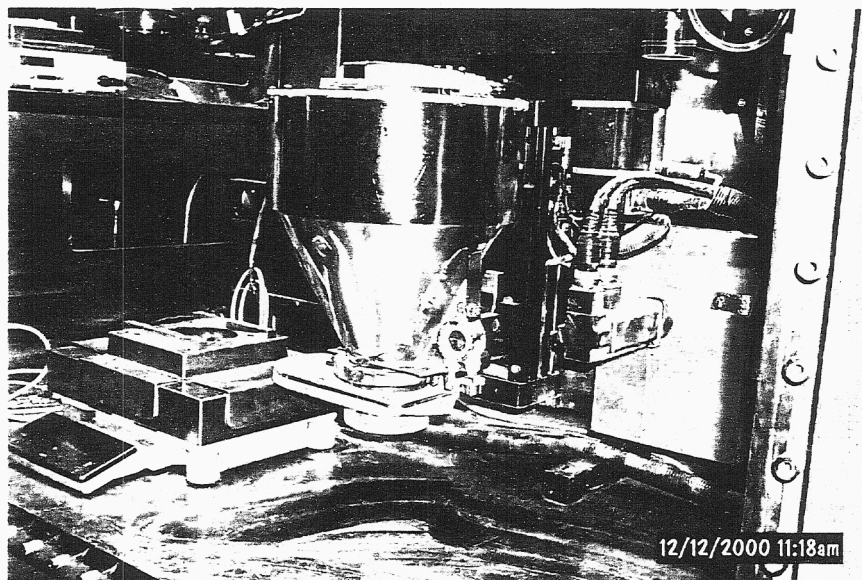


Figure 4: Photo of the Large Hopper on X2-Z2 Hopper Transporter.

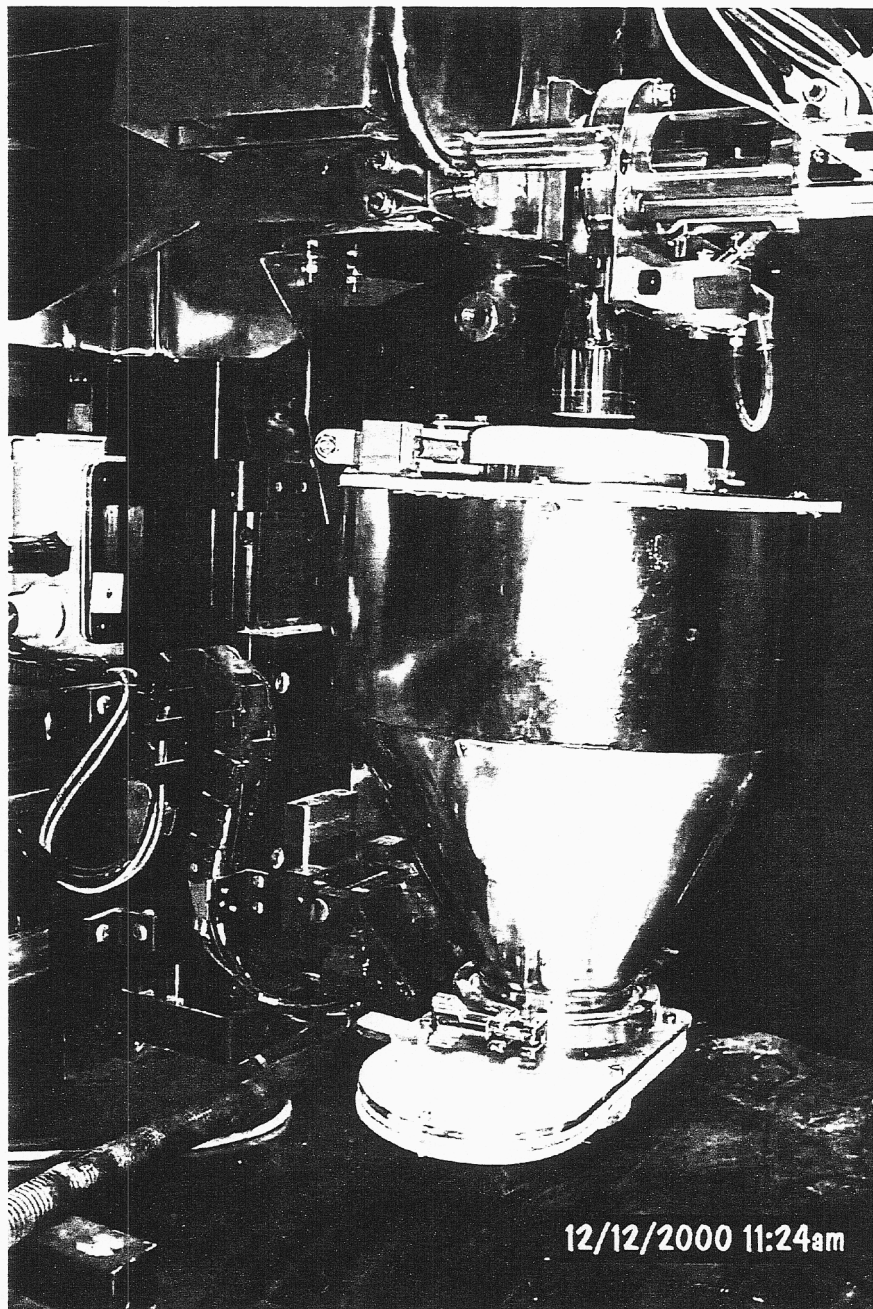


Figure 5: Photo of the Large Hopper with Cover Seal Plate opened and ready to engage with Attritor Mill Outlet Spigot .

3.2 Hopper Transport

There are nine destinations for the hoppers to reach in support of the routine PuCTF operations. This is accomplished by using three sets of two actuators with X-Z axis motion and two single actuators with Z axis motion as shown in Figure 6. All actuators are commercial linear actuators except the X2 axis which is a custom built assembly with a 4.4-

meter travel . The X2 axis actuator is custom designed and fabricated to make it possible to install through the glovebox window frame.

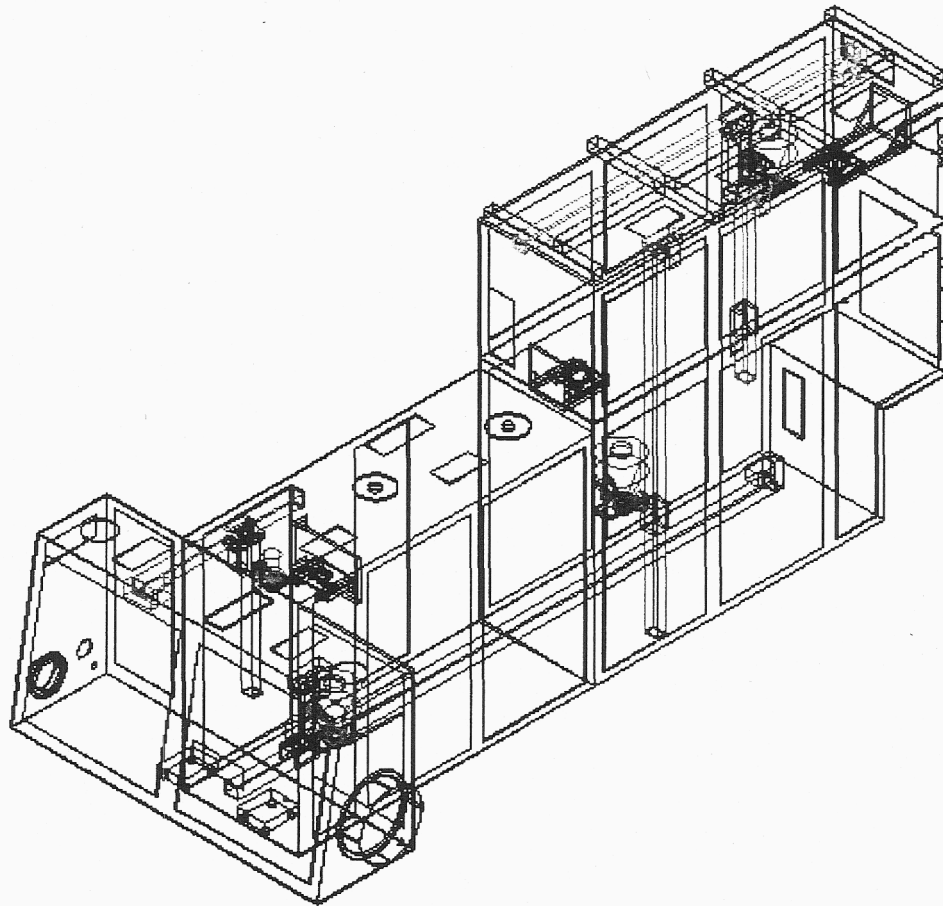


Figure 6: Isometric view of the Hopper Transport.

All linear actuators have three position sensors to establish the over-travel limits and the home position. The X1-Z1 set is dedicated to moving the Small Hopper between the scale in the material receiving line and the HSA1 Feed Docking Station. The X2-Z2 set covers the horizontal movements of the Large Hopper in the Attritor Mill and the Granulator boxes. It also interfaces with the Z3 axis to raise the Large Hopper to the ceiling height of the Granulator box as shown in Figure 7. The Z3 axis interfaces with the X4-Z4 set. The X4-Z4 set moves the Large Hopper to the Docking Stations for the HSA10 Attritor Mill, the Granulator, and the Press. The Z5 axis is dedicated to docking the Granulator Movable Station carrying the Large Hopper with the Granulator feed port for the charging operation. All Z-axis actuators are mounted on X-axis actuators for horizontal movement. In addition, all of them are equipped with a gripper or a platform to engage the hoppers. All grippers and platforms have a locking mechanism to secure the hoppers on the carrying actuator during a transition. The Large Hopper is exchanged among Z2, Z3, Z4, and Z5 axes to meet the material transfer needs. The payloads of the Large Hopper and Small Hopper Transports are 45 Kg and 20 Kg, respectively. A single brushless servomotor with close loop control drives each axis actuator. The Hopper Transport can be operated in the manual mode or

under program control in the automatic mode. In the automatic mode, the hoppers are allowed to move only pre-determined programmed sequences. This prevents any accidental material releases.

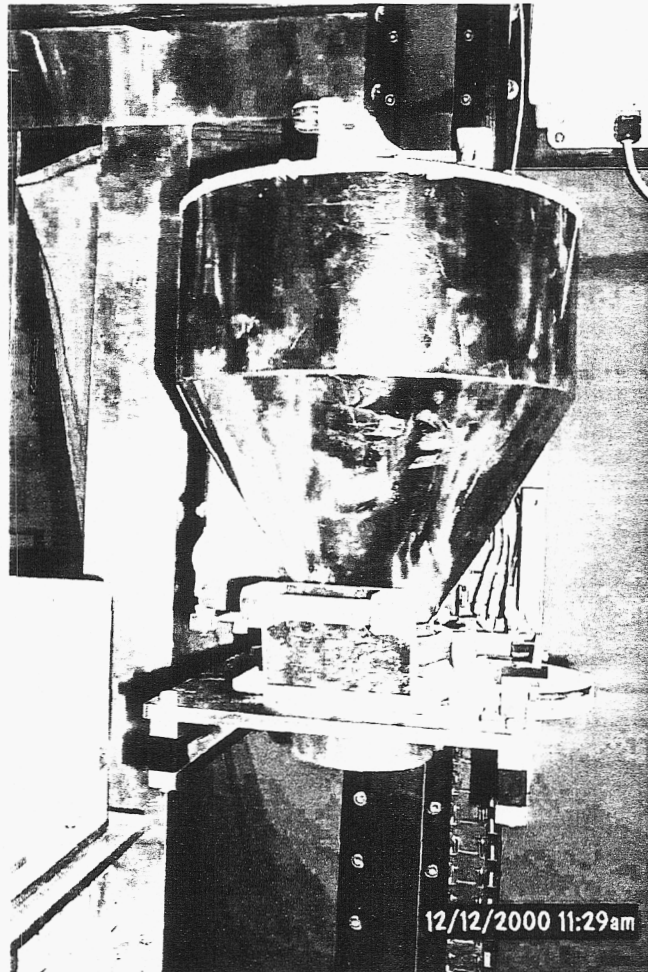


Figure 7: Photo of the Large Hopper on the Z3 platform during a vertical transit.

3.3 Docking Stations

The Docking Stations are necessary to engage the material transport hoppers to the process equipment. In the PuCTF Hopper Transport, there are three fixed Docking Stations and two movable Docking Stations. The fixed Docking Stations are for the HSA1 Attritor Mill, HSA10 Attritor Mill, and Press. The movable Docking Stations are for the Granulator. The Docking Stations are designed to engage with the hoppers. They open and close the hopper valves remotely using pneumatic actuators attached to the Docking Stations. The Docking Station for the HSA1 Attritor Mill has a pneumatic swiveling vibrator attached to it which when air activated, transmits vibrator energy to the Small Hopper while material discharges into the HSA1 Attritor Mill. However, since the Large Hopper has an integral vibrator, it can only be vibrated when engaged with the fixed air supply. The other two fixed Docking Stations for the HSA10 and the Press work similarly as show in Figure 8. They also have a pair of pneumatic cylinders to actuate the hopper valve remotely. The movable

Docking Stations are for the Granulator. One is mounted on the Z5 axis. It receives the hopper and moves it down until it mates with the Granulator. It has two valve actuators on it, one for the Large Hopper and the other one for the Granulator so it can control opening and closing of the Large Hopper and the Granulator valves remotely. The other movable Docking Station is operated by a pair of pneumatic linear actuators. It engages with the Granulator outlet valve and operates it during discharging operations. All Docking Stations float horizontally – 1/2 cm to accommodate possible misalignments.

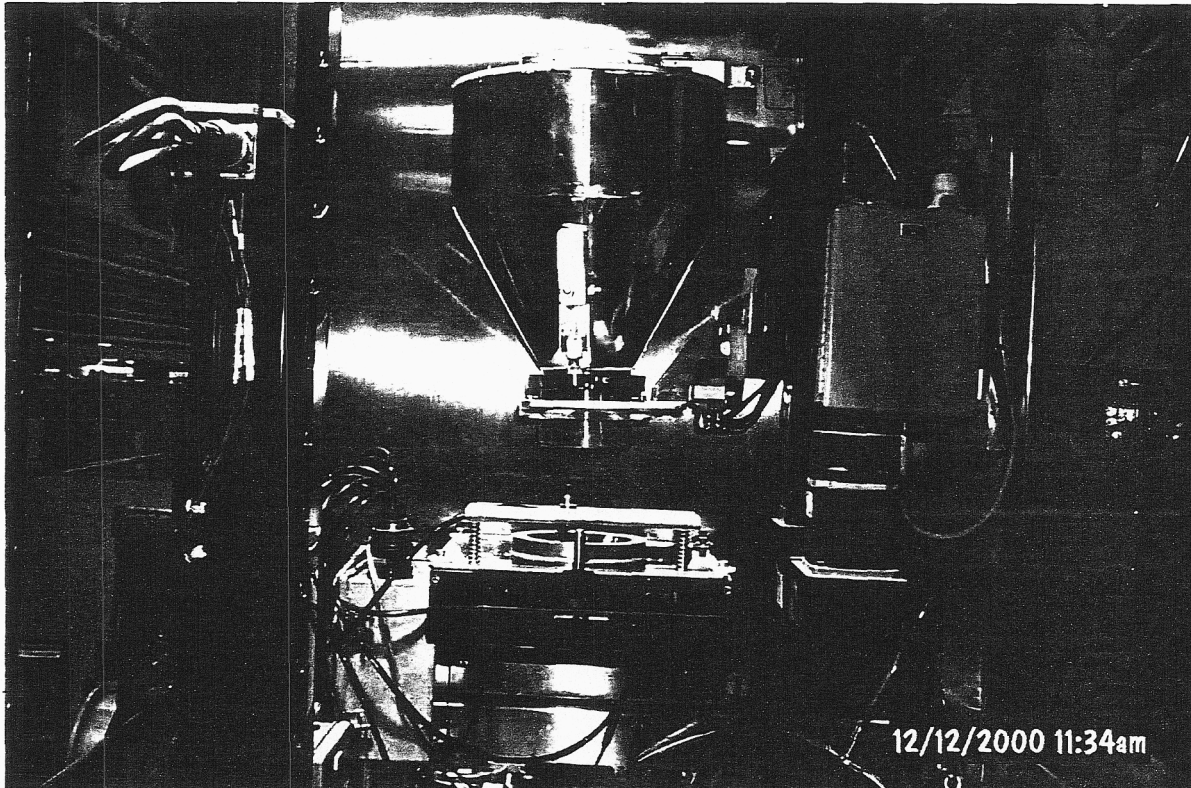


Figure 8: Photo of the Large Hopper ready to dock with the HSA10 Docking Station.

4. MATERIAL TRANSFER SYSTEM CONTROLS

The Material Transfer System² is made up of two robot systems: the Hopper Transport (HT) that moves the powder hoppers between the Attritor Mills, Granulator and Press via hopper weighing stations; and the Puck Transport (PT) that moves green pucks from the Press to Furnace, and sintered pucks from the Furnace to storage containers both via the puck Measuring Station. The puck Measuring station scans four laser ranging sensors across the puck sitting on a scale and measures its thickness, diameter, and weight. Figure 9 (a) and (b) show, respectively, the placement of the HT and PT actuator axes, hopper and puck grippers, and the feeding and discharging ports and port movable docking stations, and powder valve actuators. Figure 10 shows the placement of the dust management system vacuum manifold, collars and pump. Figure 11 shows the hopper and puck measuring stations.

² Both the puck and hopper transports were developed by CVM Corporation, Dublin, Ca.

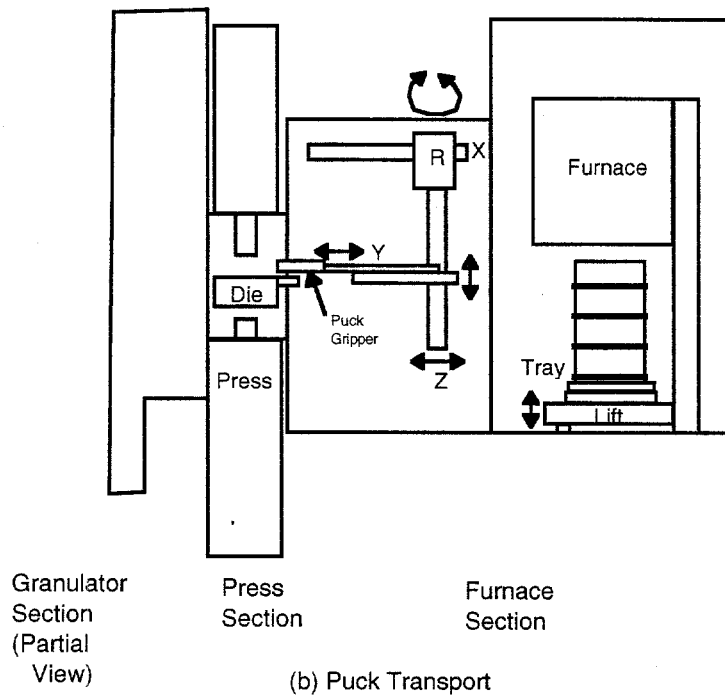
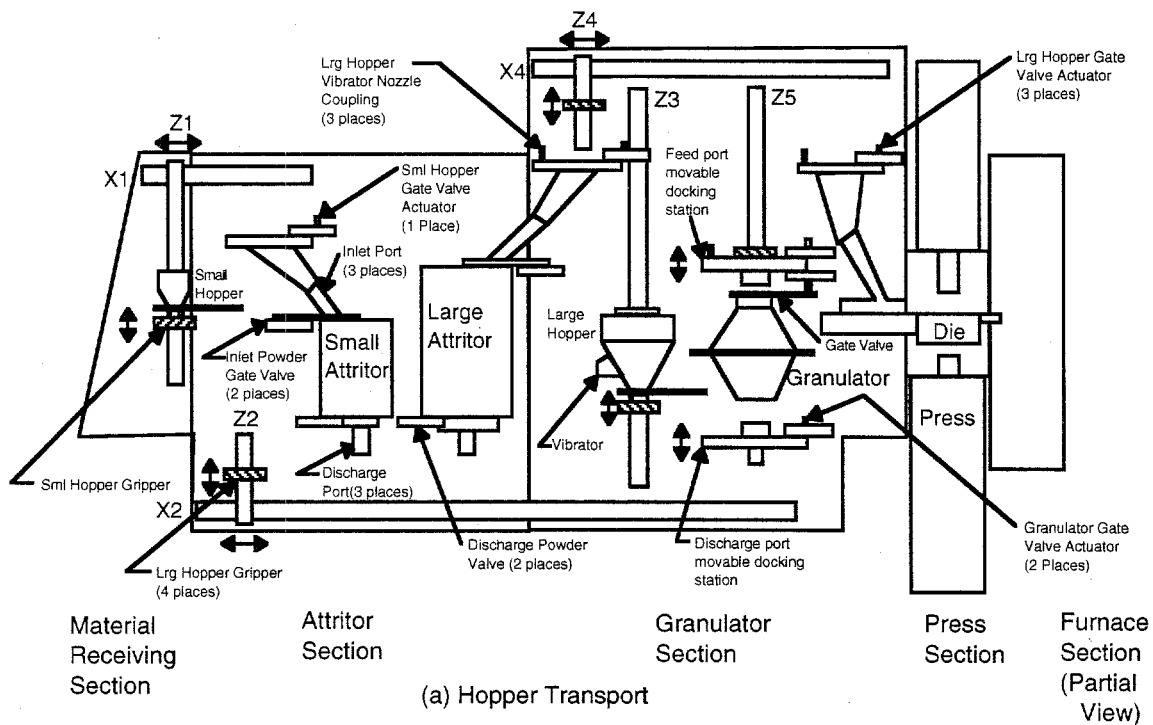


Figure 9: Material Transfer System Control Schematics.

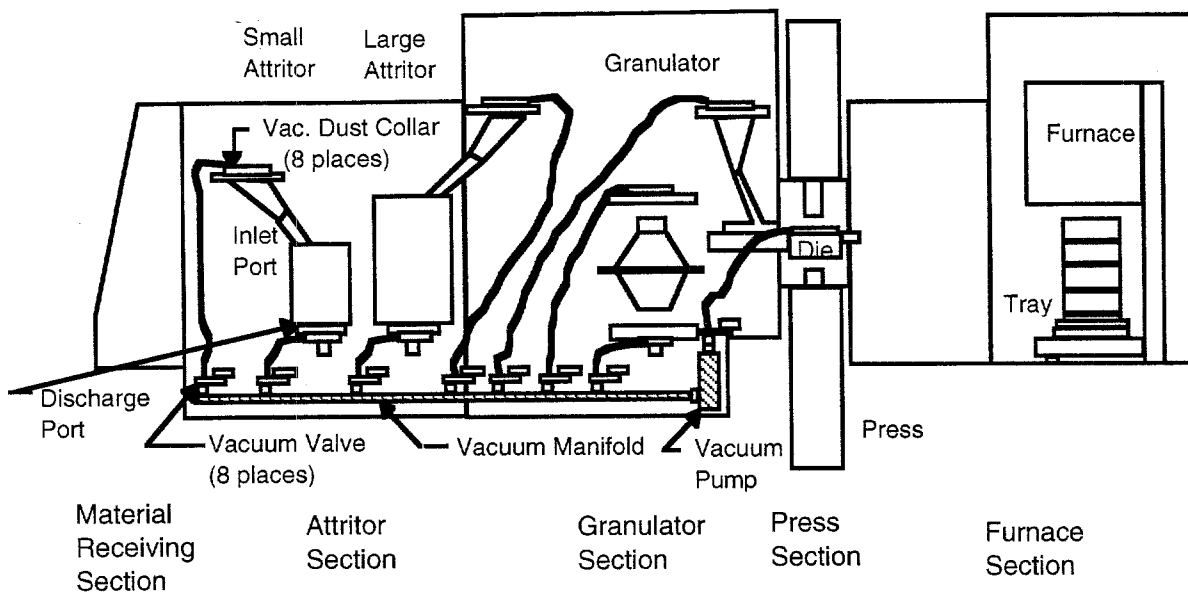


Figure 10: Hopper Transport Dust Management Vacuum System Placement.

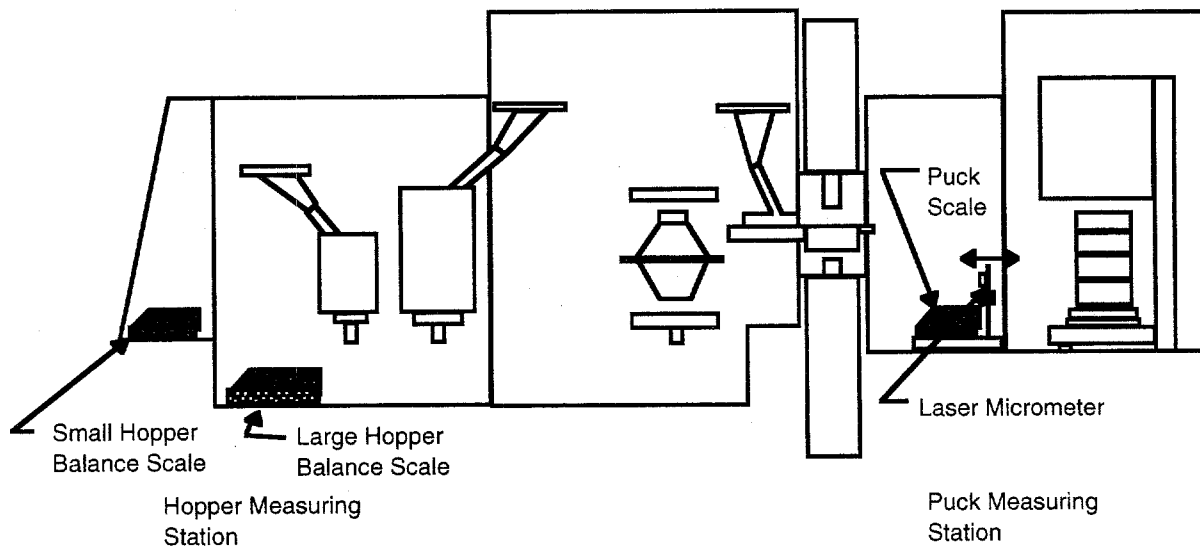


Figure 11: Hopper and Puck Measuring Station Locations.

4.1 Control Programming Environment

The controls for both the HT and PT are written in a multithreaded real-time robot control programming language³. The programs in each case are written with three sections: manual operation, homing sequence, and automatic operation. The homing sequence drives

³ QuickStep by Control Technology Incorporated.

each servomotor in the ccw direction until the associated actuator encounters the home switch or the over-travel switch. In the latter case, the program drives the servo cw far enough to insure it is beyond the home switch, then repeats the homing operation. To achieve high accuracy of the home position, the program drives the actuator off home a few tenths of an inch, reduces the acceleration and velocity profile to a slow crawl, then repeats the homing operation. In the manual operation mode, the operator can jog any of the robot actuators in either direction and open/close the gripper locks, slide gate valves, etc. It is used most often after homing in conjunction with the online monitor to determine the servo encoder counts for each position tag point of interest. The tag points are transferred to a data table where they are used in the automatic operation mode to carry out programmed moves. In the automatic mode, programmed moves directs the hopper to specific pre-defined positions according to the selected process sequence.

4.2 Control Hardware Interfaces

The HT controller interfaces with the drive amplifiers for each of eight servomotor linear robot actuators; and with discrete outputs that command air solenoid valves which power the hopper gripper actuators, the powder slide gate valves, the vibrators, the dust management vacuum valves, and the granulator feed and discharge port-movable docking stations; and with discrete inputs from the robot actuator over-travel and homing proximity switches, and the slide gate valve, vacuum valve, and gripper position sensing proximity switches. Similarly, the PT controller interfaces with drive amplifiers for each of three linear robot actuators and one rotational robot actuator; discrete outputs which command the puck mechanical air and vacuum actuated gripper solenoid valves; and discrete inputs from robot actuator over-travel and homing proximity switches, and the gripper position sensing proximity switches.

The HT and PT controllers also interface with the powder processing equipment controllers, and the hopper and puck Measuring Stations to coordinate consecutive powder processing operations.

The puck Measuring Station consists of four laser ranging sensors⁴ mounted on a yoke that is scanned over the nominal position of a puck sitting on an integral balance scale. The control program written in a process control language⁵ moves the yoke to a position at approximately one third the nominal diameter of a green puck, then sequentially steps ten times across the central third of the puck acquiring and logging the sensor data at each step position. This data is analyzed for viability, then the six contiguous samples spanning the central region of the puck are averaged for the thickness measure and interpolated for the diameter measure.

4.3 MTS Control Sequence

The MTS is used in the ceramification process as follows:

⁴ LM10 Microlaser Sensor Series by Matsushita Electric works Ltd.

⁵ LabVIEW data logging and supervisory control (BridgeVIEW) module by National Instruments.

- 1) To prepare to mill the actinide, a plutonium handler manually loads the glovebox-bagged-in actinide powder into the small hopper, and then directs the HT controller to set the hopper on the small scale, prompt the measuring station controller to weigh the hopper, wait for a permissive that weight has been acquired, dock the hopper with the small attritor inlet, open the inlet dust management vacuum valve, open the inlet isolation and hopper outlet valves to load the attritor, turn on the hopper vibrator for a specified interval to facilitate dumping the powder, close the valves, move the hopper to the small scale, and prompt the measuring station to weigh the emptied hopper. This sequence of operations may be repeated if the powder held up in the hopper is excessive.
- 2) To mill the actinide and combine it with the ceramic precursor, a plutonium handler manually loads the bagged-in precursor powder into the large hopper, and then directs the HT controller to set the hopper on the large scale, prompts the measuring station controller to weigh the hopper, wait for a permissive that the weight has been acquired, dock the hopper with the small attritor discharge port, direct the small attritor controller to mill the actinide at a specified speed for a specified interval. To combine the actinide with the precursor powder, the operator directs the HT controller to open the attritor discharge port vacuum management valve and powder discharge slide gate valve, turn on the attritor stirrer for a specified interval, close the valves, move the hopper to the large scale, and prompt the measuring station to weigh the hopper. This last sequence of operations may be repeated if the powder held up in the attritor is excessive.
- 3) To prepared to blend the actinide and precucor powder, the operator directs the HT controller to dock the large hopper with the large attritor inlet, open the inlet dust management vacuum valve, open the inlet isolation valve, open the hopper outlet valve, turn on the hopper vibrator for a specified interval, close the valves, move the hopper to the large scale, and notify the measuring station to acquire the weight of the emptied hopper. This sequence of operations may be repeated if the weight of the hopper powder holdup is excessive.
- 4) To blend the actinide and precursor powder, the operator directs the HT controller to dock the large hopper with the large attritor discharge port, and signal the large attritor controller to mill the actinide at a specified speed for a specified interval. To discharge the blended powder, the operator directs the HT controller to open the discharge port dust management vacuum valve, open the attritor discharge valve, turn on the attritor stirrer for a specified interval, close the valves, move the hopper to the large scale, and prompt the measuring station to acquire the weight of the emptied hopper. This last sequence of unloading operations may be repeated if the attritor powder holdup is excessive.
- 5) To prepare to granulate the blended powder, the operator directs the HT controller to dock the large hopper with the Granulator vessel access port. To accomplish this, the HT controller waits for a permissive from the Granulator controller signifying that its

vessel has been stopped and the access port slide gate valve end is positioned vertically up for the loading operation, then it lowers the feed port movable docking station carrying the hopper and docks it with the Granulator inlet, opens the access port dust management vacuum valve, opens the access port slide gate valve, opens the hopper slide gate valve, turns on a vibrator for a specified interval, closes the valves, moves the hopper to the large scale, raises the inlet movable docking station clear of the vessel, and acquires the hopper weight. This sequence may be repeated if the hopper holdup is excessive .

- 6) To granulate the powder, the Granulator vessel runs for a specified interval at a specified speed while injecting a specified volume of binder liquid. At completion of this process, the vessel is stopped with the access port slide gate valve positioned vertically down. To discharge the granulated powder, the HT controller waits for a permissive from the Granulator controller signifying that the access port is in the discharge position, then it raises the discharge port movable docking station so that it docks with the vessel access port, docks the hopper inlet to the discharge port movable docking station outlet, opens the access port dust management vacuum valve, opens the access port slide gate valve, turns on the vessel vibrators for a specified interval, closes the valves, moves the hopper to the scale and lowers the discharge port movable docking station clear of the Granulator vessel, and prompts the measuring station to acquire the weight of the hopper. This last sequence of unloading operations may be repeated if the Granulator powder holdup is excessive.
- 7) To prepare to press pucks, the operator directs the HT controller to move the large hopper to the Press inlet port, dock the hopper with the Press inlet port, then with a permissive from the Press controller, open the Press inlet isolation slide gate valve and hopper outlet slide gate valve to dump the powder into the Press shuttle pipe.
- 8) To press the pucks and load them into the Furnace, the operator directs the Press controller to form a green puck, the Press die dust management collar vacuum is turned on during the puck press stroke, then following the puck pressing cycle, the Press controller prompts the PT controller which then picks up the puck, places it on the puck Measuring Station, prompts the Measuring Station, waits for a permissive indicating the measurements have been acquired, sends a permissive to the Press indicating the last puck has been removed and it is okay to press the next puck, and with a permissive from the furnace that the floor lift is completely open, places the puck in an ordered configuration on the Furnace tray shelves. Repeat the above procedure (8) until all powder in the press inlet shuttle pipe has been pressed.
- 9) To unload the Furnace, following the binder burn-out and sintering cycle and the issuance of a permissive signal that the floor lift is completely open, the PT controller is directed by the operator to unload, measure and place the sintered pucks into the storage containers, one puck at a time, five pucks to a can.

5. CONCLUSION

The Material Transporting System for the plutonium ceramification line has been developed. The system was put together in the PuCTF glovebox line at a temporary staging location for the test runs. System validation testing was successful. The PuCTF system is currently being disassembled and relocated to the Plutonium Facility. The system will be reassembled and cold-tested in the Plutonium facility by the spring of 2001 and Pu operations will closely follow Plutonium Facility approval.

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

ACKNOWLEDGEMENTS

Recognition is given to Kurt Peterson, Westinghouse Savannah River Company, Aiken, GA, for his contributions to the mechanical design of the Puck Transport and the Puck Measuring Station. Jeff Takakuwa, CVM Corporation, Dublin, CA, is also recognized for his original programming of the MTS robots.